SOUND ATTENUATING/ABSORBING LAMINATES AND METHODS OF MAKING SAME

FIELD OF THE INVENTION

The present invention relates generally to vehicles and, more particularly, to trim components utilized within vehicles.

BACKGROUND OF THE INVENTION

It is generally considered desirable to reduce the level of noise within a vehicle passenger compartment. External noises, such as road noise, engine noise, vibrations, etc., as well as noises emanating from within passenger compartments, may be attenuated through the use of various acoustical materials. Accordingly, sound attenuating materials for vehicles, such as automobiles, are conventionally used in the dashboard, in conjunction with carpeting for floor panels, in the wheel wells, in the trunk compartment, under the hood, and as part of the headliner.

The attenuation of external noise is conventionally referred to as sound transmission loss (STL). The attenuation of internal noise is conventionally referred to as sound absorption. The acoustic impedance of a material is defined as material density times acoustic velocity, and is expressed in units of Rayls (Newton-seconds/meter^3). Acoustic impedance defines how easy it is for air to move through a material. Thus, for fibrous materials, acoustic impedance

depends upon the density of the fibrous material and fiber diameter. Generally, the heavier the blanket and the finer the fibers, the higher the acoustic impedance. Moreover, thicker layers typically have more acoustic impedance than thin layers. The ability of a material to attenuate noise is conventionally defined by the material's STL, acoustic impedance, and absorption characteristics.

Carpeting used to cover the floor areas of vehicles, such as automobiles, is conventionally molded into a non-planar three dimensional contoured configuration which conforms to the contours of the vehicle floor so as to fit properly. In order to make the carpeting moldable and shape-sustaining, it is conventionally provided with a backing of thermoplastic polymer composition. The thermoplastic polymer backing also serves as a barrier to improve the sound deadening properties of the carpet assembly.

Dash insulators are often mounted to a vehicle firewall which separates the passenger compartment from an engine compartment. Dash insulators are designed to reduce the transmission of noise and heat from the engine compartment into the passenger compartment. Conventional dash insulators consist of an acoustical absorber such as an open-cell polyurethane foam or a resinated fiber pad which faces the fire wall, and a barrier sheet such as a heavily filled thermoplastic material. Dash insulator barriers are conventionally produced in a compounding process followed by an extrusion or calendaring process or by an injection molding process to achieve a barrier sheet of desired thickness and width.

Conventional carpet systems and dash insulators typically include an ethylene-vinylacetate (EVA), polyethylene (PE), or polyvinylchloride (PVC) layer which serves as a barrier sheet. Unfortunately, there are several drawbacks associated with the use of EVA, PE, and

PVC layers in these vehicle applications. For example, EVA, PE, and PVC are non-porous materials which can be relatively heavy when applied to carpeting, dash insulators, and other interior trim components. In addition, EVA, PE, and PVC are conventionally applied in layers have a non-varying thickness. As such, some material may be wasted in areas where sound transmission is not problematic, thereby increasing weight unnecessarily.

Various sound attenuating materials have been developed for use in reducing noise levels within passenger compartments of vehicles. For example, U.S. Patent No. 4,851,283 to Holtrop et al., proposes a thermoformable laminate for use in headliners. The headliner comprises a non-woven fabric bonded to a foamed polymer sheet. The fabric is formed from a blend of low melting staple fibers and high melting staple fibers.

U.S. Patent No. 5,298,694 to Thompson proposes a non-woven acoustical insulation web. The web comprises thermoplastic fibers, and particularly a blend of melt-blown microfibers and crimped bulking fibers.

U.S. Patent No. 5,677,027 to Masuda et al., proposes a sound insulating structure comprising a covering layer, a panel, and a cushioning layer. The cushioning layer comprises a first fiber such as polyethylene terephthalate (PET) and a second fiber that is of a shell-core construction wherein the majority of the core is PET.

U.S. Patent No. 5,817,408 to Orimo et al., proposes a sound insulating structure which includes low and high density thermoplastic fibers. PET is preferred as a thermoplastic synthetic fiber.

U.S. Patent No. 4,529,639 to Peoples, Jr. et al. proposes a molded foam-backed carpet assembly which includes a carpet layer, a moldable thermoplastic polymer layer and one or more foam pads fusibly bonded to the

thermoplastic layer and extending over less than the entire surface of the thermoplastic polymer layer to provide desired cushioning and sound and thermal insulation only in preselected areas of the carpet.

In general, the ability of conventional materials to attenuate sound increases as the amount of material increases. Unfortunately, increased materials often increases the weight of sound attenuating material, which may be undesirable. Accordingly, there is a continuing need for acoustical insulation materials for use within vehicles that exhibit superior sound attenuating properties, while also being lightweight and low in cost.

SUMMARY OF THE INVENTION

In view of the above discussion, sound attenuating and/or absorption laminates for use within vehicles such as floor coverings and other interior trim components, and methods of producing same, are provided. According to embodiments of the present invention, a sound attenuating laminate configured to be attached to an article, such as a vehicle panel, includes a substrate having a shape of the article, and polyurethane attached to selected portions of the substrate. The polyurethane is non-porous and serves as a barrier to attenuate sound passing through the substrate. Additional non-porous polyurethane may be added to one or more selected portions of the polyurethane layer to enhance sound attenuation characteristics in the one or more selected portions. According to embodiments of the present invention, one or more of the substrate surfaces may have recessed portions formed therein, and additional non-porous polyurethane may be applied in the one or more recessed portions to further enhance sound attenuation characteristics. According to embodiments of the present invention, one or more secondary articles (*e.g.*, plastic

pass-throughs, etc.) may be molded-in with the substrate and additional non-porous polyurethane may be applied over the one or more molded-in articles to further enhance sound attenuation characteristics.

According to embodiments of the present invention, a sound absorption laminate configured to be attached to an article, such as a vehicle panel, includes a substrate having a shape of the article, and breathable polyurethane attached to selected portions of the substrate. The polyurethane serves as an absorber of sound (*e.g.*, sound generated within a vehicle compartment). Additional breathable polyurethane may be added to one or more selected portions of the polyurethane layer to enhance sound absorption characteristics in the one or more selected portions. According to embodiments of the present invention, one or more of the substrate surfaces may have recessed portions formed therein, and additional breathable polyurethane may be applied in the one or more recessed portions to further enhance sound absorption characteristics.

According to embodiments of the present invention, a porous, breathable carpet assembly (or dash insulator) for use in vehicles, is provided and includes a substrate and a porous carpet layer secured to the substrate. The substrate has opposite first and second surfaces and the porous carpet layer is adhesively secured to the substrate via a breathable polyurethane layer. The substrate first surface is configured to be attached to a vehicle panel in contacting face-to-face relationship therewith. The substrate may be formed into the shape of a vehicle floor panel (or vehicle firewall) such that the substrate first surface attaches to the vehicle floor panel (or firewall) in contacting face-to-face relationship therewith.

Breathable polyurethane may be applied onto the substrate second surface in one or more areas to enhance

sound absorption characteristics of the carpet assembly. Alternatively, or in addition to, non-porous polyurethane may be applied onto the substrate second surface in one or more areas to enhance sound attenuation characteristics of the carpet assembly (or dash insulator).

Sound attenuating and/or absorption laminates, sound absorbing carpet assemblies, and sound absorbing dash insulators, according to embodiments of the present invention, can provide desired sound deadening and absorption properties in selected vehicle locations, such as floor pans, door panels, firewalls, headliners, spare tire covers, etc. Moreover, sound attenuating and/or absorption laminates according to embodiments of the present invention may have reduced overall weight without sacrificing soundproofing properties.

BRIEF DESCRIPTION OF THE DRAWINGS

The accompanying drawings, which form a part of the specification, illustrate key embodiments of the present invention. The drawings and description together serve to fully explain the invention.

Fig. 1 is cross-sectional view of a portion of a sound attenuating laminate according to embodiments of the present invention.

Fig. 2 is cross-sectional view of a portion of a sound attenuating laminate according to other embodiments of the present invention.

Fig. 3 is cross-sectional view of a portion of a sound attenuating laminate according to other embodiments of the present invention.

Fig. 4 is cross-sectional view of a portion of a sound attenuating laminate according to other embodiments of the present invention.

Fig. 5 is cross-sectional view of a portion of a sound attenuating laminate according to other embodiments of the present invention.

Fig. 6 is a flowchart of operations for producing sound attenuating laminates of **Figs. 1-4**, according to embodiments of the present invention.

Fig. 7A is cross-sectional view of a portion of a sound absorption laminate according to embodiments of the present invention.

Fig. 7B is cross-sectional view of a portion of a sound absorption laminate according to other embodiments of the present invention.

Fig. 7C is cross-sectional view of a portion of a sound absorption laminate according to other embodiments of the present invention.

Fig. 8 is cross-sectional view of a portion of a sound absorbing laminate according to other embodiments of the present invention.

Fig. 9 is a flowchart of operations for producing sound attenuating laminates of **Figs. 7A-7C**, according to embodiments of the present invention.

Fig. 10 is cross-sectional view of a portion of a porous, breathable carpet assembly according to embodiments of the present invention.

Figs. 11-12 are perspective views of an exemplary carpet assembly for a vehicle according to embodiments of the present invention.

Fig. 13 is a perspective view of an exemplary dashboard insulator for a vehicle according to embodiments of the present invention.

Fig. 14 is a flowchart of operations for producing the carpet assembly of **Figs. 10-12**, according to embodiments of the present invention.

DETAILED DESCRIPTION OF THE INVENTION

The present invention now is described more fully hereinafter with reference to the accompanying drawings, in which preferred embodiments of the invention are shown. This invention may, however, be embodied in many different forms and should not be construed as limited to the embodiments set forth herein; rather, these embodiments are provided so that this disclosure will be thorough and complete, and will fully convey the scope of the invention to those skilled in the art.

In the drawings, the thickness of lines, layers and regions may be exaggerated for clarity. It will be understood that when an element such as a layer, region, substrate, or panel is referred to as being "on" another element, it can be directly on the other element or intervening elements may also be present. In contrast, when an element is referred to as being "directly on" another element, there are no intervening elements present. It will be understood that when an element is referred to as being "connected" or "attached" to another element, it can be directly connected or attached to the other element or intervening elements may also be present. In contrast, when an element is referred to as being "directly connected" or "directly attached" to another element, there are no intervening elements present. The terms "upwardly", "downwardly", "vertical", "horizontal" and the like when used herein are for the purpose of explanation only.

Embodiments of the present invention provide sound attenuating and/or absorbing laminates and carpet assemblies for use in various applications, particularly automotive applications. Exemplary automotive applications within which sound attenuating and/or absorbing laminates and carpet assemblies according to embodiments of the present invention may be utilized

include, but are not limited to, floor coverings, door panels, dash insulators, trunk liners headliners, various interior trim components, etc.

Referring to **Fig. 1**, a section view of a portion of a sound attenuating laminate **10** that is configured to attenuate noise according to embodiments of the present invention, is illustrated. The sound attenuating laminate **10** includes a substrate **14** having opposite first and second surfaces **14a**, **14b**. The first surface **14a** is attached to an article **12**, such as a vehicle panel, in contacting face-to-face relationship therewith. A polyurethane barrier layer **16** is applied to selected portions **15** of the substrate second surface **14b**, as illustrated. The polyurethane barrier layer **16** may also be applied to the entire second surface **14b** of the substrate. The polyurethane barrier layer **16** is non-porous and is configured to attenuate sound passing through the article (*e.g.*, vehicle panel) and through the substrate **14**.

The polyurethane barrier layer **16** has a density of about 1.0 to 3.0 pcf and a thickness of about 15 to 30 mm. The polyurethane barrier layer **16** comprises an isocyanate, a polyol and various additives such as crosslinking agents, catalysts, blowing agents and the like, the selection of which will be within the skill of one in the art. For example, the isocyanate component of the polyurethane includes one or more compounds selected from the group consisting of diphenylmethane-4, 4'-diisocyanate, diphenyldimethylmethane-4, 4'-diisocyanate, phenylene-1, 4-diisocyanate, 2,2',6,6'-tetramethyldiphenylmethane-4,4'-diisocyanate, diphenyl-4, 4'diisocyanate, diphenylether-4, 4'-diisocyanate or its alkyl-, alkoxy- or halogen-substituted derivatives, toluylene-2, 4- and -2,6-diisocyanates or their commercially available mixture, 2,4-

diisocypropylphenylene-1, 3-diisocyanate, m-xylylenediisocyanate, and p-xylylenediisocyanate.

Further, in the practice of the present invention, any desired types of polyester polyols and polyether polyols may be used as a polyol component of the polyurethane prepolymer solution. Examples of the crosslinking agent usable in the present invention include trifunctional or more functional polyisocyanate or hydroxyl compounds, for example, one or more compounds selected from the group consisting of ethylene glycol, propylene glycol, butane-1, 4-diol, hexane-2, 5-diol, 2,2-dimethylpropane-1, 3-diol, hexane-1,6-diol, 2-methylhexane-1,6-diol, 2,2-dimethylhexane-1,3-diol, p-bishydroxymethyl cyclohexane, 3-methylpentane-1, 4-diol, 2,2-diethylpropane-1, 3-diol and the like. As the catalyst, tertiary amines, organic tin compounds, organic lead compounds and the like may be used. As the solvent capable of dissolving polyols and isocyanates, methyl ethyl ketone, ethyl acetate, toluene, xylene, dimethylformamide, methyl isobutyl ketone, butyl acetate, acetone or the like may be used alone or in combination. The polyurethane barrier layer **16** can be in the form of a slab foam, cast foam or a thermoformable foam.

According to embodiments of the present invention, the polyurethane may include a filler, such as calcium carbonate, calcium hydroxide, aluminum trihydrate, talc, bentonite, barytes, silica, clay and mica.

An exemplary unfilled polyurethane barrier material that may be used in accordance with embodiments of the present invention is Bayer Elastomer (Bayer AG, Pittsburgh, PA). An exemplary filled polyurethane barrier material that may be used in accordance with embodiments of the present invention is Huntsman Rimline SH 80309 (Huntsman Corporation, Salt Lake City, Utah).

The substrate **14** may be formed from any type of

material including, but not limited to foam (*e.g.*, polyurethane foam, thermoplastic foam, etc.), massback, and other thermoformable fibrous materials including those derived from natural and synthetic fibers. Massback is a relatively dense material, normally impermeable to air and thermoformable. Massback can be formed from virtually any plastic or rubber material which contains a high-mass filler material. An exemplary massback includes ethylene-vinylacetate (EVA) copolymer, polyethylene, or polyvinyl-chloride (PVC), and a high-mass filler material, such as glass, calcium carbonate or barium sulfate, added to increase the mass. Other suitable materials for the substrate include thermoformable stiff thermoplastic materials such as polystyrene, polyphenyl sulfide and polycarbonate, fiber-reinforced thermoplastics and fiber-reinforced thermosets such as epoxies, phenolics and the like.

The substrate **14** may be formed into a three-dimensional shape of the article **12** such that the substrate first surface **14a** attaches to the article **12** in contacting face-to-face relationship therewith. The substrate **14** can have form retention characteristics such that it maintains a form imposed upon it. Alternatively, the substrate **14** may have elastic memory such that it is unable to maintain an unassisted non-flat configuration. For substrate materials having elastic memory, the polyurethane barrier layer **16** also serves the function of a binder such that the substrate **14** can maintain a shape imposed upon it via molding and other operations.

The article **12** may be virtually any type of vehicle panel (*e.g.*, floor panel, firewall, door panel, wheel well, trunk compartment panel, etc.). For example, a sound attenuating laminate **10** according to embodiments of the present invention may be utilized as a dash insulator when attached to a vehicle firewall, may be

utilized as a floor covering when attached to vehicle floor panels, and may be utilized as virtually any type of vehicle interior trim component.

Vehicle panels to which sound attenuating laminates according to the present invention may be attached may have various shapes, configurations, and sizes, and may be formed of various materials including, but not limited to metals, polymers, and combinations thereof. For example, a vehicle panel may be sheet metal having a three-dimensional configuration. Alternatively, a vehicle panel may be a substantially flat piece of sheet metal.

Referring to **Fig. 2**, a sound attenuating laminate **110** according to other embodiments of the present invention is illustrated. The illustrated sound attenuating laminate **110** includes a substrate **14** having opposite first and second surfaces **14a**, **14b**. The first surface **14a** is attached to an article **12**, such as a vehicle panel, as illustrated. A polyurethane barrier layer **16** is applied to the substrate second surface **14b**, and additional polyurethane **16'** is added to a selected portion **17** of the polyurethane layer **16**. Both the polyurethane barrier layer **16** and the additional polyurethane **16'** are preferably non-porous polyurethane and are configured to attenuate sound passing through the article **12** and through the substrate **14**. The additional polyurethane **16'** is added to a specific location determined to require additional sound attenuation.

Referring to **Fig. 3**, a sound attenuating laminate **210** according to other embodiments of the present invention is illustrated. The illustrated sound attenuating laminate **210** includes a substrate **14** having opposite first and second surfaces **14a**, **14b**. The first surface **14a** is attached to an article **12**, such as a vehicle panel, as illustrated. A polyurethane barrier

layer **16** is applied to the substrate second surface **14b**, and additional polyurethane **16'** is disposed within a recess **19** formed within the substrate first surface **14a**. Both the polyurethane barrier layer **16** and the additional polyurethane **16'** are non-porous polyurethane and are configured to attenuate sound passing through the article **12** and through the substrate **14**. The additional polyurethane **16'** is added to the recess **19** to enhance sound attenuation characteristics of the sound attenuating laminate **210** in the area of the recess **19**.

Referring to **Fig. 4**, a sound attenuating laminate **310** according to other embodiments of the present invention is illustrated. The illustrated sound attenuating laminate **310** includes a substrate **14** having opposite first and second surfaces **14a, 14b**. A recess **21** is formed within the substrate second surface **14b**. The first surface **14a** is attached to an article **12**, such as a vehicle panel, as illustrated. A polyurethane barrier layer **16** is applied to the substrate second surface **14b** such that it also fills the recess **21** formed within the substrate second surface **14b**. The polyurethane barrier layer **16** is a non-porous polyurethane and is configured to attenuate sound passing through the article **12** and through the substrate **14**. The additional polyurethane **16** due to the recess **21** enhances sound attenuation characteristics of the sound attenuating laminate **310** in the area of the recess **21**.

Sound attenuating laminates according to embodiments of the present invention illustrated in **Figs. 3-4** can have various numbers of recesses filled with non-porous polyurethane. Moreover, recesses filled with non-porous polyurethane may have various configurations and/or sizes.

Referring to **Fig. 5**, a sound attenuating

laminate **410** according to other embodiments of the present invention is illustrated. The illustrated sound attenuating laminate **410** includes a substrate **14** having opposite first and second surfaces **14a**, **14b**. A secondary article (*e.g.*, a plastic pass-through) **23** is molded-in with the substrate **410**. The first surface **14a** is attached to an article **12**, such as a vehicle panel, as illustrated. In the illustrated embodiment, the article **12** includes an aperture that is in communication with the aperture in the secondary article **23**. Accordingly, an item, such as a cable, can be extended through the article aperture and through the sound attenuating laminate **410**.

A polyurethane barrier layer **16** is applied to the substrate second surface **14b** such that it overlies the molded-in secondary article **23** and surrounding area. The polyurethane barrier layer **16** is a non-porous polyurethane and is configured to attenuate sound passing through the article **12** and through the substrate **14**. The additional polyurethane **16** enhances sound attenuation characteristics of the sound attenuating laminate **410** in the area of the molded-in secondary article **23**. Secondary articles molded-in with substrates according to embodiments of the present invention can have various sizes, shapes, and configurations.

Referring now to **Fig. 6**, operations for forming sound attenuating laminates, according to embodiments of the present invention, are illustrated. The acoustic properties of an article, such as a vehicle panel, on which a sound attenuating laminate is to be placed are ascertained to identify areas requiring additional sound attenuation characteristics. (Block **1000**). Acoustic properties of an article may be ascertained by identifying areas of an article through which sound within a predetermined frequency range passes at an

intensity level that exceeds a threshold intensity level. Identifying areas of an article through which sound within a predetermined frequency range passes at an intensity level that exceeds a threshold intensity level may include generating a sound intensity map of the article. Sound intensity maps are well understood by those skilled in the art and need not be described further herein.

A substrate configured to be attached to the article in face-to-face contacting relationship is formed into a shape corresponding to that of the article (Block **1010**). Areas of the substrate in which apertures are to be formed therethrough may be identified (Block **1020**). Polyurethane is then applied (*e.g.*, via spraying or other application techniques) to the substrate in areas identified as requiring enhanced sound attenuation characteristics (Block **1030**). Areas of the substrate in which apertures are to be formed therethrough are preferably avoided during the application of the polyurethane barrier layer. Additional polyurethane may be added to areas identified as requiring additional sound attenuation characteristics (Block **1040**). This may encompass applying additional polyurethane directly onto an existing polyurethane barrier layer and/or into one or more recessed portions formed within the substrate.

According to embodiments of the present invention, various ones of the operations illustrated in **Fig. 6** may be performed out of the illustrated order. For example, polyurethane may be added to various portions of a substrate prior to forming (*i.e.*, molding) operations. As another example, a substrate may be formed prior to the application of any polyurethane. As another example, polyurethane may be applied within a mold and additional polyurethane added in selected locations. A substrate may then be attached to the polyurethane and the composite article formed via the mold into a desired shape.

Furthermore, operations represented by Blocks **1030** and **1040** may be performed substantially simultaneously. For example, additional polyurethane can be added by adjusting processing speeds and/or by adjusting dispensing pressure, as would be understood by those skilled in the art.

Referring now to **Figs. 7A-7C**, section views of portions of sound absorbing laminates, according to embodiments of the present invention, are illustrated. In **Fig. 7A**, a sound absorbing laminate **40** includes a substrate **44** having opposite first and second surfaces **44a**, **44b**, and a layer of breathable polyurethane **46** disposed on the substrate second surface **44b**. In the illustrated embodiment, the substrate first surface **44a** is attached to an article **42** (*e.g.*, a vehicle panel) in face-to-face relationship therewith. The breathable polyurethane layer **46** is configured to enhance sound absorption characteristics. For example, sound generated within a vehicle can be absorbed by the sound absorbing laminate **40** to provide a quieter environment within the vehicle.

The breathable polyurethane layer **46** has a density of about 1.0 to 3.0 pcf and a thickness of about 15 to 30 mm. The breathable polyurethane layer **46** comprises an isocyanate, a polyol and various additives such as crosslinking agents, catalysts, blowing agents and the like, the selection of which will be within the skill of one in the art. For example, the isocyanate component of the polyurethane includes one or more compounds selected from the group consisting of diphenylmethane-4, 4'-diisocyanate, diphenyldimethylmethane-4, 4'-diisocyanate, phenylene-1, 4-diisocyanate, 2,2',6,6'-tetramethyldiphenylmethane-4,4'-diisocyanate, diphenyl-4, 4'diisocyanate, diphenylether-4, 4'-diisocyanate or its alkyl-, alkoxy-

or halogen-substituted derivatives, toluylene-2, 4- and -2,6-diisocyanates or their commercially available mixture, 2,4-diisocypropylphenylene-1, 3-diisocyanate, m-xylylenediisocyanate, and p-xylylenediisocyanate.

Further, in the practice of the present invention, any desired types of polyester polyols and polyether polyols may be used as a polyol component of the polyurethane prepolymer solution. Examples of the crosslinking agent usable in the present invention include trifunctional or more functional polyisocyanate or hydroxyl compounds, for example, one or more compounds selected from the group consisting of ethylene glycol, propylene glycol, butane-1, 4-diol, hexane-2, 5-diol, 2,2-dimethylpropane-1, 3-diol, hexane-1,6-diol, 2-methylhexane-1,6-diol, 2,2-dimethylhexane-1,3-diol, p-bishydroxymethyl cyclohexane, 3-methylpentane-1, 4-diol, 2,2-diethylpropane-1, 3-diol and the like. As the catalyst, tertiary amines, organic tin compounds, organic lead compounds and the like may be used. As the solvent capable of dissolving polyols and isocyanates, methyl ethyl ketone, ethyl acetate, toluene, xylene, dimethylformamide, methyl isobutyl ketone, butyl acetate, acetone or the like may be used alone or in combination. The breathable polyurethane layer **46** can be in the form of a slab foam, cast foam or a thermoformable foam.

According to embodiments of the present invention, the breathable polyurethane layer **46** may include a filler such as calcium carbonate, calcium hydroxide, aluminum trihydrate, talc, bentonite, barytes, silica, clay and mica.

An exemplary breathable polyurethane material that may be used in accordance with embodiments of the present invention is Bayer Baypreg SA (Bayer AG, Pittsburgh, PA).

The substrate **44** may be formed from any type of material including, but not limited to foam (*e.g.*,

polyurethane foam, thermoplastic foam, etc.), massback, and other thermoformable fibrous materials including those derived from natural and synthetic fibers. Massback is a relatively dense material, normally impermeable to air and thermoformable. Massback can be formed from virtually any plastic or rubber material which contains a high-mass filler material. An exemplary massback includes ethylene-vinylacetate (EVA) copolymer, polyethylene, or polyvinyl-chloride (PVC), and a high-mass filler material, such as glass, calcium carbonate or barium sulfate, added to increase the mass. Other suitable materials for the substrate include thermoformable stiff thermoplastic materials such as polystyrene, polyphenyl sulfide and polycarbonate, fiber-reinforced thermoplastics and fiber-reinforced thermosets such as epoxies, phenolics and the like.

The substrate **44** may be formed into the shape of the article **42** such that the substrate first surface **44a** attaches to the article **42** in contacting face-to-face relationship therewith. The substrate **44** can have form retention characteristics such that it maintains a form imposed upon it. Alternatively, the substrate **44** may have elastic memory such that it is unable to maintain an unassisted non-flat configuration. For substrate materials having elastic memory, the layer of breathable polyurethane **46** also serves the function of a binder such that the substrate **44** can maintain a shape imposed upon it via molding and other operations.

As illustrated in **Fig. 7B**, a sound absorbing laminate **140**, according to embodiments of the present invention may include additional breathable polyurethane **46'** added to one or more selected portions **47** of the layer of breathable polyurethane **46**. Both the layer of breathable polyurethane **46** and the additional polyurethane **46'** are configured to absorb sound. The

additional polyurethane **46'** is added to a specific location determined to require additional sound absorption.

As illustrated in **Fig. 7C**, a sound absorbing laminate **240**, according to embodiments of the present invention may include upholstery material **48** attached to the polyurethane layer **46** in face-to-face contacting relationship therewith.

According to embodiments of the present invention, the sound absorbing laminates of **Figs. 7A-7C** may include one or more recessed portions formed within the substrate and additional breathable polyurethane is disposed therewithin as described above with respect to the sound attenuating laminate embodiments of **Figs. 1-4**. In addition, according to embodiments of the present invention, the sound absorbing laminates of **Figs. 7A-7C** may include one or more molded-in secondary articles within the substrate and additional breathable polyurethane may be disposed thereon and/or therearound as described above with respect to the sound attenuating laminate embodiments of **Figs. 1-4**.

The article **42** to which sound absorbing laminates **40, 140, 240** according to the embodiments of **Figs. 7A-7C** may be attached may be virtually any type of vehicle panel (*e.g.*, floor panels, firewalls, door panels, wheel wells, trunk compartment panels, spare tire covers, headliners, etc.). For example, a sound absorbing laminate according to embodiments of the present invention may be utilized as a dash insulator when attached to a vehicle firewall, may be utilized as a floor covering when attached to vehicle floor panels, and may be utilized as virtually any type of vehicle interior trim component. Vehicle panels to which sound absorbing laminates illustrated in **Figs. 7A-7C** may be attached may have various shapes, configurations, and sizes, and may

be formed of various materials including, but not limited to metals, polymers, and combinations thereof. For example, a vehicle panel may be sheet metal having a three-dimensional configuration. Alternatively, a vehicle panel may be a substantially flat piece of sheet metal.

Referring to **Fig. 8**, a sound absorbing laminate **340** according to other embodiments of the present invention is illustrated. The illustrated sound absorbing laminate **340** includes a substrate **44** having opposite first and second surfaces **44a**, **44b**, and a layer of breathable polyurethane **46** disposed on the substrate second surface **44b**. A secondary article (*e.g.*, a plastic pass-through) **23** is molded-in with the substrate **340**. In the illustrated embodiment, the article **42** includes an aperture that is in communication with the aperture in the secondary article **23**. Accordingly, an item, such as a cable, can be extended through the article aperture and through the sound absorbing laminate **340**. The breathable polyurethane layer **46** overlies the molded-in secondary article **23** and surrounding area and is configured to enhance sound absorption characteristics. For example, sound generated within a vehicle can be absorbed by the sound absorbing laminate **40** to provide a quieter environment within the vehicle. Secondary articles molded-in with substrates according to embodiments of the present invention can have various sizes, shapes, and configurations.

Referring now to **Fig. 9**, operations for forming sound absorbing laminates, according to embodiments of the present invention, are illustrated. The acoustic properties of a vehicle within which a sound absorbing laminate is to be placed are ascertained to identify areas that require additional sound absorption characteristics. (Block **2000**).

A substrate configured to be attached to the

article in face-to-face contacting relationship is formed into a shape corresponding to that of the article. (Block **2010**). Areas of the substrate in which apertures are to be formed therethrough may be identified. (Block **2020**). Breathable polyurethane is then applied (*e.g.*, via spraying or other application techniques) to the substrate in areas identified as requiring enhanced sound absorption characteristics. (Block **2030**). Areas of the substrate in which apertures are to be formed therethrough are preferably avoided during the application of the polyurethane barrier layer. Additional polyurethane may be added to areas identified as requiring additional sound absorption characteristics (Block **2040**). This may encompass applying additional breathable polyurethane directly onto an existing layer of breathable polyurethane and/or into one or more recessed portions formed within the substrate.

According to embodiments of the present invention, various ones of the operations illustrated in **Fig. 9** may be performed out of the illustrated order. For example, polyurethane may be added to various portions of a substrate prior to forming (*i.e.*, molding) operations. As another example, a substrate may be formed prior to the application of any polyurethane. As another example, polyurethane may be applied within a mold and additional polyurethane added in selected locations. A substrate may then be attached to the polyurethane and the composite article formed via the mold into a desired shape.

Furthermore, operations represented by Blocks **2030** and **2040** may be performed substantially simultaneously. For example, additional polyurethane can be added by adjusting processing speeds and/or by adjusting dispensing pressure, as would be understood by those skilled in the art.

Referring now to **Fig. 10**, a section view of a

portion of sound absorbing carpet assembly **50**, according to embodiments of the present invention, are illustrated. The sound absorbing carpet assembly **50** includes a substrate **54** having opposite first and second surfaces **54a**, **54b**. A porous carpet layer **58** is adhesively secured to the substrate, either via a breathable polyurethane layer **56**, or via another adhesive layer (not shown). The illustrated carpet layer **58** includes a backing **60** and carpet tufts **62** extending from the backing **60**. The backing **60** is in contacting face-to-face relationship with the breathable polyurethane layer **56**.

The substrate first surface **54a** is configured to be attached to a vehicle floor panel **52** in contacting face-to-face relationship therewith. The substrate **54** may be formed from any type of material including, but not limited to foam (*e.g.*, polyurethane foam, thermoplastic foam, etc.), massback, and other thermoformable fibrous materials including those derived from natural fibers, man-made fibers, and/or blends of natural fiber and man-made fibers.

The substrate **54** may be formed into the shape of a vehicle floor panel **52** such that the substrate first surface **54a** attaches to the vehicle floor panel **52** in contacting face-to-face relationship therewith. The substrate **54** can have form retention characteristics such that it maintains a form imposed upon it. Alternatively, the substrate **54** may have elastic memory such that it is unable to maintain an unassisted non-flat configuration. For substrate materials having elastic memory, the breathable polyurethane layer **56** also serves the function of a binder such that the substrate **54** can maintain a shape imposed upon it via molding and other operations.

An exemplary porous, breathable carpet assembly **50** is illustrated in **Fig. 11**. The illustrated carpet assembly **50** has a non-planar three dimensional molded

configuration adapted to fit the front seat compartment floor of a vehicle and includes a raised medial portion **61** adapted to conform to the transmission hump, generally vertically extending side portions **62** adapted to fit beneath each door opening, and a front portion **63** adapted to fit along the inclined floorboard and vertical firewall areas of a vehicle. Various openings or cut-outs are provided, as indicated at **64**, to receive air conditioning equipment, the steering column, pedals and the like. It is to be understood that the particular three dimensional configuration illustrated is merely for purposes of illustration. Carpet assemblies according to embodiments of the present invention may have various configurations and shapes depending on the floor configuration of a vehicle.

Referring to **Fig. 12**, additional polyurethane **70** is added to one or more selected portions of the substrate first surface **54a** of the carpet assembly **50**. The additional polyurethane **70** may be a breathable polyurethane such that sound absorption characteristics of the carpet assembly **50** are enhanced. Alternatively, The additional polyurethane **70** may be a non-porous polyurethane such that sound attenuation characteristics of the carpet assembly **50** are enhanced. Moreover, there may be a combination of breathable polyurethane and non-porous polyurethane such that both sound absorption and sound attenuation characteristics of the carpet assembly **50** are enhanced.

An exemplary porous, breathable dashboard insulator **80** is illustrated in **Fig. 13**. The illustrated dashboard insulator **80** has a non-planar three dimensional molded configuration adapted to fit the firewall of a vehicle. Various openings or cut-outs are provided, as indicated at **64**, to receive air conditioning equipment, the steering column, pedals and the like. It is to be

understood that the particular three dimensional configuration illustrated is merely for purposes of illustration. Dashboard insulators according to embodiments of the present invention may have various configurations and shapes depending on the firewall configuration of a vehicle. Additional polyurethane may be added to one or more selected portions of the dashboard insulator as described above. The additional polyurethane may be a breathable polyurethane such that sound absorption characteristics of the dashboard insulator **80** are enhanced. Alternatively, the additional polyurethane may be a non-porous polyurethane such that sound attenuation characteristics of the dashboard insulator **80** are enhanced. Moreover, there may be a combination of breathable polyurethane and non-porous polyurethane such that both sound absorption and sound attenuation characteristics of the dashboard insulator **80** are enhanced.

Referring now to **Fig. 14**, operations for producing a carpet assembly **50** (**Figs. 10-12**) for use in vehicles, according to embodiments of the present invention, are illustrated. The acoustic properties of a vehicle within which a carpet assembly is to be utilized are ascertained. (Block **3000**). A substrate having opposite first and second surfaces is provided, wherein the substrate first surface is configured to be attached to a vehicle panel in contacting face-to-face relationship therewith (Block **3010**). A layer of uncured, breathable polyurethane is applied onto the substrate second surface (Block **3020**). A porous carpet layer is attached to the substrate such that the carpet layer backing is in contacting face-to-face relationship with the breathable polyurethane layer (Block **3030**). The carpet layer and substrate are then formed into a desired shape (Block **3040**). The breathable polyurethane layer is

then subjected to conditions sufficient to cure breathable polyurethane layer such that the substrate and carpet layer are bonded together to form a porous, breathable carpet assembly having the desired shape (Block **3050**). For example, heat and/or other energy forms (*e.g.*, microwave energy) may be applied to cure the polyurethane layer.

Breathable polyurethane may be applied onto the substrate second surface in one or more areas to enhance sound absorption characteristics of the carpet assembly (Block **3060**). Alternatively, or in addition to, non-porous polyurethane may be applied onto the substrate second surface in one or more areas to enhance sound attenuation characteristics of the carpet assembly (Block **3070**).

Sound attenuating laminates and sound absorbing laminates according to the various embodiments of the present invention facilitate acoustical "tuning" wherein acoustical "hot spots" can be identified and additional material (*i.e.*, non-porous polyurethane to provide a barrier to sound, and/or breathable polyurethane to absorb sound) can be added to attenuate sound. Sound attenuating laminates according to embodiments of the present invention can be "tuned" to provide desired sound attenuating characteristics in selected vehicle locations, such as floor panels, firewalls, door panels, wheel wells, trunk compartment panels, etc. The term "tuned" means that portions of a sound attenuating and/or absorbing laminate can be formed to have a specific acoustic impedance designed to attenuate sound in one or more frequencies or frequency bands, and/or to have a specific absorption characteristic designed to absorb sound in one or more frequencies or frequency bands. Moreover, sound attenuating/absorption laminates according to embodiments of the present invention may have reduced overall weight compared with conventional

sound proofing materials, and without sacrificing sound attenuation properties.

The foregoing is illustrative of the present invention and is not to be construed as limiting thereof. Although a few exemplary embodiments of this invention have been described, those skilled in the art will readily appreciate that many modifications are possible in the exemplary embodiments without materially departing from the novel teachings and advantages of this invention. Accordingly, all such modifications are intended to be included within the scope of this invention as defined in the claims. Therefore, it is to be understood that the foregoing is illustrative of the present invention and is not to be construed as limited to the specific embodiments disclosed, and that modifications to the disclosed embodiments, as well as other embodiments, are intended to be included within the scope of the appended claims. The invention is defined by the following claims, with equivalents of the claims to be included therein.